Identifying and Using Precursors

A gateway to gate-to-gate safety enhancement

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I - Introduction

I.1 - Forewords

This paper is intended for all actors of the aviation community, regardless of their role, type of equipment and operation.

Although the views and examples reflected herein are largely based on the author's experience (observations and lessons learned), gained in the frame of his various former roles and through his contributions to industry projects, they are intended to be immaterial as they may be applicable or adapted to any ground-based or airborne operation.

I.2 - Scope and objectives

The scope of this article is to revisit some key aspects of the overall process involved in identifying precursors of incident / accidents, analyzing the associated risk factors (active threats and latent pathogens), and using the resulting lessons-learned for developing related defenses (for prevention purposes) and controls (for detection and recovery, or mitigation).

This paper also is intended to constitute a useful resource for the reader; indeed, the appended summary tables may be used to illustrate and support the following overview but, also, may be used to support the reader's safety role within his/her organization.

These syntheses are provided as **Appendices 1** thru **4** :

- **Appendix 1** – Incidents / Accidents – Precursors – Risk Factors – Defenses / Controls;
- **Appendix 2** – Risk Domains – Defenses / Controls - Implicit Operating Safety Models;
- **Appendix 3** – Challenged Operating Assumptions; and,
- **Appendix 4** – Quotes About Prevention and Precursors.

Note : Appendix 5 summarizes the author's former roles in commercial aviation and contributions to industry projects that have inspired the following overview.

The core article and its appendices are intended to elicit questions and answers from the reader about :

- How does this apply to my company, organization and operation ?
- How do we achieve this objective, in a similar or equivalent manner ?
- Where and how could we achieve more in terms of identification, analysis and use of precursors ?

II - Safety Vision - Prevention

II.1 - Prevention in a nutshell

The overall concept and process of incident / accident prevention start with the intimate awareness of existing hazards and associated risks, in terms of severity and probability.

The identification of high-risk domains and associated risk factors (threats, in a broad understanding) paves the way for the development of risk reduction strategies (defenses and controls).

Such a sensible and practical vision of incident / accident prevention is therefore goal and product oriented.

Prevention is all about trapping / mitigating risk factors before they are allowed (by environmental conditions and circumstances) to stack-up / line-up in a way that may lead to a major incident or accident.

In aviation, no one operates alone, prevention is therefore a shared challenge that involves all actors as well as the way they interface / interact.

Each actor is responsible for a part of the building blocks that constitute the basic elements of safety, but he/she is also responsible for how well these building blocks fit into the global structure.

An effective safety vision therefore requires a holistic approach, as illustrated by **Figure 1**.

Figure 1

The basic elements of safety

II.2 – Adopting a double definition of prevention

Enhancing safety involves strengthening our defenses related to past accidents and incidents, but also to uneventful events.

Prevention is therefore to be understood as a two-pronged strategy aimed at :

- Preventing the recurrence of known types-of-events; and,
- Preventing the occurrence of potential events.

The latter refers to the prevention of events that :

- Occurred already although being uneventful, but that could have a more severe outcome under different circumstances; or,
- Did not occur yet, but could foreseeably occur under an adverse combination of factors and set of circumstances.

Preventing these potential events requires the detection / identification of early warnings and weak signals that constitute the precursors of possibly more severe and/or harmful events.

To embrace this two-pronged strategy, our industry had to shift from a paradigm of causes (forensic / clinical analysis of events) to a paradigm of symptoms (predictive analysis of early warnings / weak signals / precursors).

II.3 – Challenges in dealing with precursors

The endeavor of identifying, analyzing and using precursors, in any high-risk industry and organization, inevitably faces challenges; indeed, as opposed to the process of incident / accident investigation :

- The incident or accident did not occur … yet;
- No damage has been done;
- Management attention is, therefore, low; and,
- Prioritization is, correspondingly, low for resources and money spending.

However, making precursors visible implies the moral and legal duty to evaluate them further and take action, thus, ensuring their end-to-end resolution.

The analysis of precursors is now an integral component of every safety management system.

III - Defining Precursors

III. 1 – Precursors (early warnings, weak signals, tremors, …)

Precursors are the pre-warnings of known or potential hazards, such early warnings may be :

- Known already … but so far ignored … until possibly revealed by a real event; or,
- Unknown, as undetected - as such - by past analysis.

Precursors may be classified as either :

- Uneventful occurrences / events that might have a more severe outcome; or
- Procedural / flight path deviations that may be observed randomly but could become combined and, thus, result in a major occurrence.

Precursors also include latent pathogens that may lie within the organization (i.e., policies, procedures, accepted practices, …).

Analytical methods and tools must help making precursors detectable and visible.

Revealing precursors requires the analysis and correlation of a large number of data collected through multiple reporting schemes (as developed in paragraph **V.1**), in order to fill the gaps within individual data sets and connect the dots between different data sets.

The **Appendix 1** provides, for each major risk domain (i.e., type-of-accident to be prevented), a list of typical precursors (uneventful occurrences and deviations) along with the defenses and controls that are available to trap / mitigate associated risk factors / threats and, thus, prevent precursors from taking place.

Flight path deviations often are identified by the flight data analysis and monitoring process (FDA / FDM), whereas procedural deviations usually are revealed by flight crew's interviews conducted in the frame of this process or by line observations collected in the frame of a line operations assessment process.

The risk factors (threats) that may contribute to the occurrence of precursors (whether procedural / flight path deviations or uneventful events) are not listed in **Appendix 1**, but a cross-reference to the various industry prevention programs, education and training aids and toolkits, in which they are listed, is provided by Notes 1 thru 10.

IV – Defining Safety Models and Operating Assumptions

IV.1 – Global safety models

Although several industry safety initiatives have been devoted to the development of global safety models, reflecting the complexity of the aviation system, no such model is yet available for worldwide use.

Most global projects were devoted to capturing the dependencies (inter-relationships) that exist between various event causal sequences (causality chains) leading to the same potential event or to different types-of-event.

Such causal sequences are reflecting the hierarchy and functional relationships between all the risk factors, defenses and controls that govern the prevention … or the occurrence … of a given type-of-event.

Dependency models are primarily intended to identify the weak links / paths in the prevention / recovery / mitigation process and to integrate / propagate the lessons learned from in-service occurrences, in order to confirm or challenge the robustness (effectiveness and reliability) of various defenses and controls.

This dynamic feed-forward / feed-back process is also intended to automatically generate warnings on unanticipated / undetected combinations of, or interactions between, various risk factors / defenses / controls.

In addition, some models also attempt to capture cross-boundary risks that may stem from the interfacing between different domains and actors of the aviation system (e.g., flight operations / air traffic control, flight operations / maintenance, flight operations / ground handling, flight operations / airport operation, …).

In an ultimate development of the above global approach, a few models also enable assessing the risk variation with changing conditions (i.e., assessing how and why a given flight – linking a given city-pair - presents more risks today than it did yesterday).

However, only a few of these powerful models have reached industrial maturity and affordability.

It is fair to highlight, at this point, that traditional classification models have been continuously enhanced over the past decade to encompass new descriptors, keywords and markers for the encoding of new aspects and risk factors, such as :

- Event / occurrence originator (trigger, root cause);
- Consequences on flight conduct and continuation;
- Operational and human performance factors (including threat and error management);
- Environmental factors and circumstances; and,
- Organizational / systemic factors.

Classification systems and associated taxonomies are aplenty within the industry, although some efforts have been aimed at defining a common taxonomy.

Nevertheless, the nature of information to be captured and analyzed depends - to a large extent - on the role of the collecting organization within the overall aviation system (e.g., certification agency, oversight authority, manufacturer, airline, air navigation service provider, airport operator, …).

Current classification systems either focus on encoding a single category of factors (e.g., pure human factors, threat and error management markers, …) or they integrate the encoding of all the observed operational and human performance factors (considered in their broadest understanding).

Classification models usually do not allow capturing dependencies (interactions) between causality links and/or paths, but they easily allow identifying the most frequently observed descriptors, keywords and markers (the "big bars", with reference to bar-graphs) which, in turn, allows assessing where resources and money can be spent most effectively.

IV.2 - Implicit Safety Models

Until complex global dependency safety models are in wide use across our industry, our collective aviation safety model will continue to consist, instead, in the compilation of individual agreed-upon / implicit models.

These historical models often have been shaped by applicable regulations and amendments thereto and/or have been progressively developed and refined by the industry, based on the hard-won lessons learned from decades of experience.

The **Appendix 2** proposes a list of such implicit safety models.

This list does not claim to be exhaustive but it is believed to constitute a fair cross section of standards that implicitly govern the flight operations segment of our industry.

IV.3 - Operating assumptions

When developing any complex system - i.e., its design principles, operating procedures and training concept - every organization considers, explicitly or implicitly, a set of assumptions about :

- The prior experience (airmanship / craftsmanship) of the user;
- How the user will behave;
- What the user will always do … or never do;
- What the user will know about the system operation … and how to operate the system;
- What information will be available to the user concerning the operating environment; and,
- […].

These assumptions – or expectations – are consciously or unconsciously derived from the individual safety models discussed in paragraph **IV.1** and listed in **Appendix 2**.

Although these assumptions have sustained the test-of-time, it should be recognized that the real world often differs from the ideal world defined in our implicit models.

Indeed, the most deeply-rooted beliefs may happen to be challenged, as wisely recalled by Ann Azevedo (US Federal Aviation Administration, Safety Analyst), during the Flight Safety Foundation - International Aviation Safety Seminar - 2005 :

“ Never assume that something will never happen …

… Do not assume that something is equal to zero, it is just lower than or much lower than a value ”.

The paragraph **VI.6** will address further the paramount need and importance for developing an educated mindset and alertness to challenging our operating assumptions.

V – Data Reporting – Data Collection

V.1 – Data reporting

Due to the subtle nature of safety data / information required to enable the capture and identification of early warnings / weak signals / precursors, the support of a just reporting culture - that encourages the blame-free flow of safety information - is undoubtedly a success-critical prerequisite.

The quality and diversity of reported data is crucial in order to … “ get visibility on events and gather facts and data … otherwise we have only opinions “, as restlessly stressed by Jim Burin - Director, Technical Programs - Flight Safety Foundation.

The capture and identification of incidents / accidents precursors requires the correlation, integration and consolidation of safety data from multiple reporting schemes, such as :

- Training feedback :
  - Indeed, " precursors of accidents are regularly observed during simulator sessions " notes Captain Hugh Dibley (British Airways / Airbus, retired); this clearly underscores the importance of training feedback to other company organizations;
- Operational feedback :
  - Pilots' reports (air safety reports, human factors reports, …);
  - Flight data analysis (data trend analysis, deviations analysis / crew interviews, …);
  - Line observations (line operations assessment markers, …);
- Organizational feedback :
  - Survey / audit reports;
  - Change functional hazard analysis (FHA of change-induced risks);
- Incident / accident investigation :
  - Investigation reports;
- Industry information sharing / feedback :
  - Lessons learned from other operators or actors.

It should be acknowledged that not every organization has access to all the information sources listed above; for instance, operators have access to the whole host of information - but only for their own operation - while manufacturers have access only to the data and information that are shared by operators - but by all operators - in the frame of the continued airworthiness process or - voluntarily and confidentially - for further safety enhancement.

The sharing of safety data / information related to cross-boundary hazards / risks certainly requires further consideration by our industry and the opening of new avenues of cross-domains information sharing.

The Global Aviation Safety Network (GAIN) devoted considerable efforts to promoting information sharing between various aviation industry domains and actors; the reports of the various GAIN working groups are available at http://flightsafety.org/archives-and-resources/global-aviation-safety-network-gain .

VI – Data Analysis

VI.1 – General

Data analysis is all about transforming data into information, information into knowledge, knowledge into lessons-learned and lessons-learned into actions / interventions.

Data analysis must support a holistic approach that considers all actors and all factors, and the way they interface between / interact with each other.

Collecting and analyzing data from multiple reporting channels allows to identifying the precursors of :

- Known hazards / risk domains;
- Emerging hazards;
- Future hazards; but also …
- Missed hazards, from the past.

A typical safety data analysis workflow usually includes the following main phases :

- Understanding the facts and reasons :
  - what happened and how (facts and data) ?
  - why did it happen (breached defenses and controls) ?

- Reviewing applicable standards :
  - basic elements of airmanship / operations golden rules, operating and training standards;

- Identifying operational and human performance factors :
  - How did the crew recognize and diagnose the situation ?
  - What were the crew decisions and actions ?
  - How well did the crew perform, in handling the contingency while managing the flight ?
  - What were the prevailing environmental conditions and circumstances (threats, …) ?

- Formulating problem statements, lessons-learned and possible interventions;

- Defining selected prevention strategies / interventions (defenses and controls);

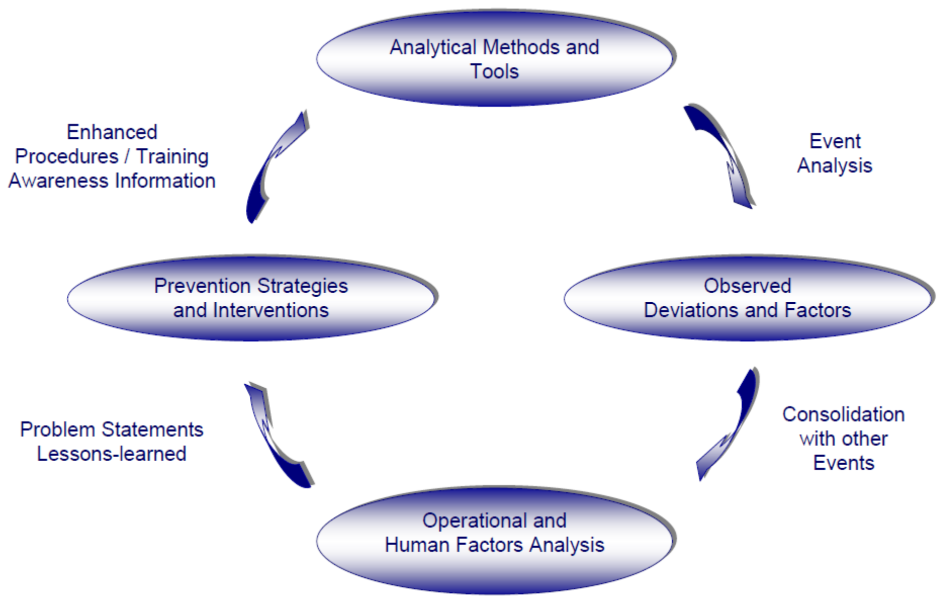
- Developing associated products (operating standards, training standards, safety awareness information, …, retrofit of available technologies).

In analyzing safety data, the context is as important as the information; in particular, operational and human performance factors should be considered not in isolation but in association, and in their operational context.

Figure 2 summarizes the various phases of a typical flight safety enhancement loop.

Figure 2

Flight safety enhancement loop



VI.2 - Analytical methods and tools

First and foremost, the selected analytical method(s) and tool(s) must be both deployable and sustainable within the organization.

Sophisticated models and powerful analysis tools are undoubtedly appealing … but their wide deployment within the organization and their sustained and effective use over years may well challenge both the human and financial resources of the company.

Whatever the method and tool, the success lies in the organization's ability to sustain the effort over years in order to take full advantage of the benefit of insight and hindsight to maximize safety enhancements.

Today, most operators tend to adopt a threat-and-error-management (TEM) approach in the analysis of safety data. In this context, threats are considered as contingencies that add complexity to operations and, thereby, increase the potential for error.

Threat and error management is a concept that recognizes the influence of threatening outside factors, affecting human performance in the dynamic work environment (formulation adapted from Air Transport World – issue October 2005).

Top-down and bottom-up analysis concepts often have been opposed, whilst they actually complement each other and usually converge towards similar multi-faceted conclusions and recommendations.

Analytical methods and tools for the processing of aviation safety data abound.

The GAIN working group B conducted a very large identification and evaluation of all such methods and tools, as available at the turn of the century, the resulting reports are available at :

http://flightsafety.org/archives-and-resources/global-aviation-safety-network-gain/example-of-analytical-tools .

VI.3 – Quantitative and qualitative analysis

How sophisticated and automated an analytical tool may be, a dose of educated guess and engineering judgment must be retained in order to take full advantage of the analyst's subject-matter-expertise and, thus, enable subtle correlations with similar events or seemingly dissimilar events.

Indeed, objective data (hard / quantitative) and subjective data (qualitative) must be integrated in order to help painting a more comprehensive / integrated risk picture and, thus, reach more balanced and complete conclusions.

The respective merits of quantitative and qualitative data are well reflected by Professor Nancy Leveson (Massachusetts Institute of Technology - MIT), in the following quotes :

" Quantifying only what can be quantify does not provide a realistic estimate of risk "; and,

" The quality of a quantitative approach depends on how good the qualitative one was ".

Professor Leveson's contention is further echoed by Roel Berendsen (Vice President, Aviation, ESR Technologies), when he notes " risk analysis in aviation employs statistical methods but most of the work includes qualitative assessments ".

Experience and hindsight are particularly paramount in :

- Recognizing the risk spirals / risk cascades that may lead to a major event; and/or,
- Correlating different data sources for a given event … and/or for similar events … in order to fill the gaps and connect the dots.

In a nutshell, an effective analysis of safety data must be based on a well-dosed mix of hard data, subjective data, knowledge and experience.

Indeed, a given hazard may not be statistically significant but a single occurrence … although random … may be deadly.

VI. 4 – Formulating problem-statements

The formulation of problem-statements helps eliciting observations and recommendations from a single analyst or from an analysis panel.

This concept was pioneered by the US Commercial Aviation Safety Team (CAST) and was subsequently adopted by the European Joint Safety Strategy Initiative - JSSI (an initiative that is now integrated into the European CAST - ECAST) and by a number of industry actors.

Formulating problem-statements typically includes the following steps :

- Raising the problem :
  - Do we have a problem ? … or … We have a problem !
- Formulating accurately the problem :
  - What went wrong and why ?
- Gathering relevant information to further document the problem :
  - What are the challenges ?
  - Why is this important ?

The implementation of a problems-statement approach should include the use of a trade-specific master problems list in order to assess whether the same problems are repeating and/or whether new ones are surfacing.

VI.5 - Identifying precursors

When analyzing an uneventful event, the first and natural response is to look forwards to identifying the more severe / harmful event(s) that could possibly occur under a more adverse set of circumstances.

Less intuitive is the fact of looking backwards to identify the first weak signals / precursors (early warnings) that went unnoticed in past analysis and, thus, allowed the uneventful event to take place.

Figure 3

Identifying first precursors

Looking backwards means researching previously experienced similar events, with the same or different scenarios / factors / causality chains, in order to identify the weak links / paths / patterns that had gone undetected by past analysis.

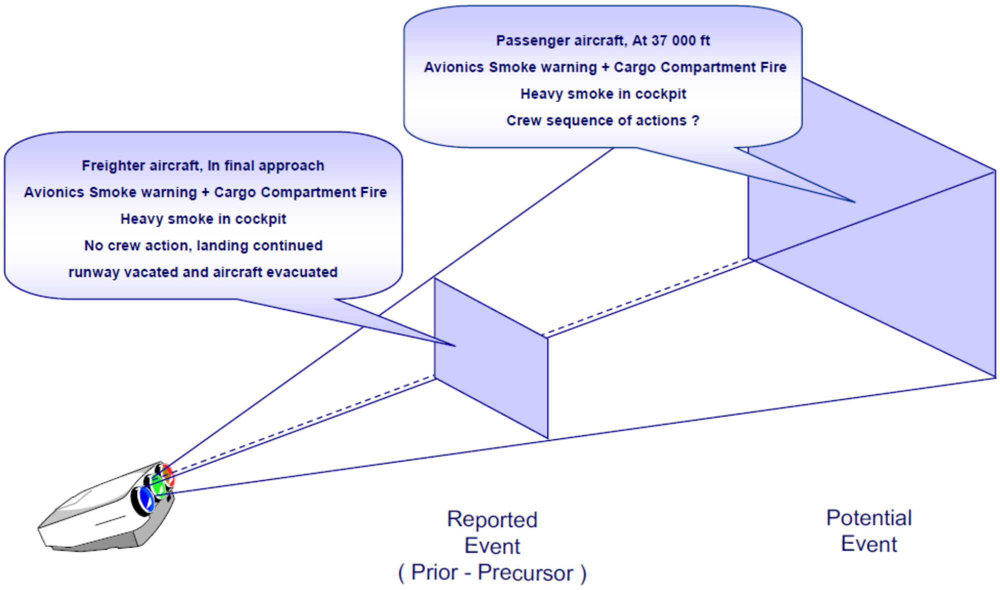
Further enhancements in flight operations safety certainly lie in the capture and identifications of these early warnings and in their effective trapping / mitigation.

In this context, " trapping / mitigation " should be understood as the trapping of threats in order to lessen the probability of the resulting errors and the mitigation of errors in order to lessens the criticality of the resulting unsafe conditions / undesired aircraft states.

Looking forwards is looking beyond the reported occurrence to identify the likely scenario of potential events that could be more challenging for the flight crew under a more adverse set of circumstances, and possibly result in a more severe / harmful outcome.

Figure 4

Looking beyond reported events



Such potential events should be evaluated with the same thoroughness as real events and should equally generate enhanced prevention strategies, defenses and controls.

The analysis of safety data should not be limited to recurring events but should also include selected first-time-occurrences / single-occurrences, based on their potential for a more severe outcome under different circumstances.

One of the underlying objectives in the development of dynamic dependency safety models was the automatic detection of precursors and unsafe causality paths.

Although appealing, this approach has been hampered by the longer-than-expected development time of these models and by their limited deployment across our industry.

Last, but certainly not least, when striving to identify incident / accident precursors, " one should never leave any stone unturned ".

VI.6 – Challenging our operating assumptions

Defenses and controls reflect decades of lessons-learned, but due to the ever changing nature of our industry, a well-thought analysis process would not be complete without challenging the robustness (i.e., effectiveness and reliability) of commonly agreed-upon and deep-rooted operating assumptions.

A typical list of such operating assumptions is provided, for illustration, as **Appendix 3**.

The table provides a categorized list of implicit operating assumptions that have been challenged in one or more in-service occurrences analyzed by the author (uneventful events, incidents or accidents), regardless of the type of equipment (make and model) and operation.

This sample list is far from being exhaustive; it could be further expanded by formulating all the operating assumptions that may be derived from the individual safety models listed in **Appendix 2**.

Indeed, precursors bring free opportunities to understand day-to-day operations as they are (i.e., not as one wish they should be), and to reassess / adapt our defenses and controls (policies, procedures, operating and training standards, flight information, safety-awareness information, …), as required.

Challenging our operating assumptions should not be solely a set process built into the analysis tool but it rather should be a mindset, supported by the analysis tool or by separate guidelines, … a mindset to looking beyond the obvious.

With this mindset in mind, we must remain humble … " we need to maintain a reasonable level of doubt ", as often advocated by Captain Bertrand de Courville – Air France.

VI.7 – Assessing risk variation with changing conditions

Risk levels vary with varying conditions, for a given hazard and associated risk factors (threats), risks levels may largely differ depending on whether they are assessed for the entire company network, for a given route or for a given flight.

The prevalence of risk factors and precursors should therefore be re-assessed for changing conditions, as discussed in paragraph **IV.1**.

Indeed, the risk level may change significantly from one flight to an other due to changes in risk factors / threats, such as :

- Dispatch under minimum equipment list (MEL) or configuration deviation list (CDL);
- Crew factors, such as :
  - Experience on type / pairing of low-time-on-type crewmembers;
  - Route / airport familiarization (absence thereof);
  - Duty time / fatigue;
- Weather conditions, enroute and at destination;
- NOTAMs :
  - Unserviceable navaids / letdown aids at destination;
  - Work-in-progress at destination airport; and,
- […].

To assess risk variations with changing conditions, risk evaluation checklists / risk assessment tools (RAT) have been developed in the frame of several industry efforts led by the Flight Safety Foundation (these tools are referenced in the **Appendix 1** – Notes 1 thru 10).

Some threat-related or flight-phase-related risk assessment tools use a threat-and-error management approach that combines the identification of the prevailing threats, the scoring of the resulting risks and a list of related mitigations strategies and best practices.

Risk assessment tools should be used during the flight preparation / dispatch briefing, the most salient points should be recalled during the takeoff briefing and the approach / go-around briefing.

VI.8 – Cross-boundary risks

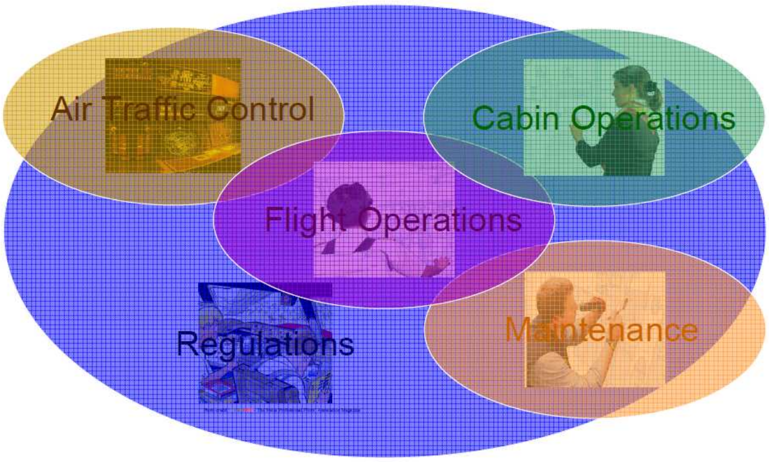
" No one operates alone ! ", as emphatically stated by David Learmount (Safety Editor, Flight International) and illustrated by **Figure 5**.

Indeed, the aviation system is a very complex and intertwined working environment, the interfacing of actors from different domains usually results in positive interactions … but also, sometimes, in negative interactions.

The hazards / risks resulting from such interactions are usually referred to as cross-boundary or cross-boarder hazards / risks.

Figure 5

No one operates alone !



Cross-boundary hazards can be identified and analyzed using trade-specific functional hazard analysis (FHA) methods and tools.

The extent and impact of cross-boundary hazards / risks can be better understood and mitigated by mapping the respectively owned and shared hazards / risks.

This risk mapping (also referred to as a risk correlated cartography) will also help identifying any case of intentional or unintentional migration or transfer of risks from one domain to an other.

Cross-boarder synergies should be implemented to effectively mitigate the hazards / risks that cannot be eliminated.

Indeed, acknowledging the outstanding level of safety already achieved, further sizeable enhancements in aviation safety will be made possible only by exploring more deeply the cross-boundary hazards / risks, as well as the change-induced risks, discussed in paragraph **VI.9**, below.

VI.9 – Change-induced risks

Although introduced for good reasons, changes carry their own risks; any change in the design principles of a system, its operating procedures and/or its training practices should be carefully evaluated to assess any foreseeable condition that could constitute a potential risk.

Assessing change-induced risks is usually performed using a functional hazard analysis (FHA) process, based on a trade-specific methodology or assessment tool.

For example, the opening of a new company route, using new destination / alternate / refueling airports and new airspace / airway systems should be subjected to such a functional hazard analysis.

Similarly, any change in company's policies and procedures also should be evaluated for potential risks.

Assessing change-induced risks should also include some degree of educated guess in order to identify past changes that had not been recognized at the time as carrying some risk.

This requires having both a vision of the future and a vision of the past.

The need to identify / recognize the early signals of threats resulting from changes is entirely captured by the following quote :

" To produce the extraordinary benefits of a [safety management system], it needs people who have real organization experience and the ability to manage data and processes ...

… They must be able to observe a fleet's flight operations and identify negative trends before the trend becomes a problem …

… It takes experience and insight to realize that a new rash of flaps overspeed events probably has something to do with the new descent procedure that was introduced in the previous month …

… these professionals have to turn data into insight, and insight into practical actions; that takes a combination of new skills and old wisdom ".

Bill Voss – President and CEO, Flight Safety Foundation – AeroSafety World journal – January 2008

The analysis of change-induced risks should include equally short-term changes and medium / long-term changes.

In Europe, the identification of future hazards (resulting from planned and foreseeable changes in our aviation system) was first tackled by the JAA - Future Aviation Safety Team (FAST); this effort is now an integral part of the European CAST (ECAST).

The functional hazard analysis of future changes should assess how future changes will affect the prevalent problems of today (either mitigating or, possibly, exacerbating their effects).

The prevention of future hazards / risks lies - for a large part - in the prevention of today precursors and in the mitigation of today risk factors.

In this context, foresight in evaluating changes and paradigm shifts is all about assessing the following leading fundamentals of any change process :

- Know what, why, how, where and when.

VII - Identifying Lessons Learned and Interventions

Formulating problem statements also includes the explicit formulation of lessons-learned and the evaluation of possible interventions :

- Evaluate possible interventions (existing or new) :
  - What are the possible solutions ?

Lessons-learned reflect the observed operational and human performance factors and challenged operating assumptions that have not been addressed yet, by past analysis, or need to be further addressed.

Associated interventions should be defined in order to be relevant, effective, reliable and affordable.

Interventions should help the front-line user in … being aware, in order to be mentally prepared.

Interventions intended for a wide range of users also should help the reader in answering the following questions, at company / organization level and at personal level :

- How could this apply to my company / organization / operation ?
- How could this apply to me ?

Interventions also should be multi-faceted in order to address the targeted hazard(s) from all possible angles, as illustrated by **Figure 6**.

Figure 6

Hazard prevention strategies

	Technology	Operating Standards	Training Standards	Safety Awareness
Hazard	✓	✓	✓	✓

Safety awareness information should not be a substitute for the enhancement of manufacturer's / company's operating and training standards; it rather should be a complement thereto.

More broadly, defining interventions should not be limited to enhancing technologies, operations, training and safety awareness information, … interventions also must be aimed at enhancing relevant ICAO standards and recommended practices, as well as governing international and/or national laws and associated regulations.

VIII – Using Lessons Learned – Implementing Interventions

The final part of a close-the-loop safety management system includes the following phases :

- Implementing the selected interventions; and,
- Monitoring the effectiveness and reliability (robustness) of interventions.

The deployment, implementation and monitoring process depends very much on whether the scope of interventions is applicable to :

- A single company / organization;
- An activity domain; or,
- The whole industry.

The deployment and implementation of interventions should be staged geographically, as applicable, targeting successively local, regional and global actors.

When dealing with industry-wide efforts, partnerships are required to support the deployment / implementation of education and training aids, prevention programs, toolkits, …, that, usually, have been jointly developed by the partnering organizations.

Figure 7 illustrates the wide array of partnerships that needs to be considered; typically, this encompasses international organizations, regional and national authorities, trade associations, industry actors, … but also civil servants involved in the basic and vocational education and initial training.

Figure 7

Partnerships in deployment / implementation process

IX – Concluding Remarks

The overall process of safety management, including identifying and using precursors, should be a process fostering both pragmatism and humbleness; indeed, nothing ever should be taken for granted.

Yves Benoist, former Vice President - Flight Safety - Airbus, used to recall restlessly that " most accidents involve aircraft that are perfectly airworthy and operated by airlines that are fully regulatory compliant "; …

… this gives, if need be, an overarching justification to furthering our endeavor to identify, analyze and use to full advantage early warnings, weak signals, tremors, …, whatever we may name the precursors of incidents / accidents.

In our commercial aviation industry, as well as in any other complex industrial domain, where measurement often is the sole rule, the merits of safety enhancement efforts should not be discounted because of incidents or accidents that have been experienced but, rather, should be appreciated for all the potential disasters that have been avoided.

Appendix 1

Incidents / Accidents and Associated Precursors

(Compiled by author – 1995 - 2010)

Incidents Accidents	**Precursors**		**Risk Factors**	**Defenses / Controls**
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Ground Collision **(Takeoff)** **(Landing)**	Taxiway confusion Runway confusion Runway incursion Takeoff or landing on taxiway Airport confusion Wildlife incursion	Callsign confusion Current airport diagram not reflecting critical changes Failure to resolve doubts / ambiguities during taxi Inadvertent deviation from cleared taxi route Takeoff without clearance Landing without clearance Incorrect ATIS information Lack of English proficiency Incorrect or confusing / misleading ATC instructions Use of non-standard phraseology by pilot and/or controller Inadequate management / separation of takeoffs and landings	Note 1	Industry prevention strategies and best practices (Note 1) Callsign deconflicting program Awareness of runway markings, signage and lighting systems in use (standard / non-standard) Use of current airport diagrams Awareness of airport " hot spots " Awareness of relevant NOTAM's (including work-in-progress) Adherence to SOP's (task sharing, briefings, use of checklists, standard calls, mutual crosscheck and backup) Adopting the same PF / PNF role allocation from-gate-to-gate (without changeover of PF / PNF roles during taxi) Performing a detailed taxi briefing, as part of takeoff briefing, for enhanced and shared situational awareness Adherence to sterile-cockpit rule Effective pilot / controller communications (readback / hearback) Active listening of ATC and other aircraft communications Management of interruptions and distractions Confirming runway designator, heading, edges and centerline lighting for positive runway identification after line-up Enhanced lookout, in case of intersection takeoff Effective use of ground-based or aircraft technologies

Incidents Accidents	Precursors		Risk Factors	Defenses / Controls
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Runway Excursion or Overrun **(Takeoff)**	Takeoff from taxiway Runway confusion Inappropriate intersection takeoff or takeoff from incorrect intersection Line-up events Rejected takeoff (whether initiated below or above 100 kt) Tire burst Aircraft swerve / lateral excursion during takeoff roll Cautions / warnings (genuine or spurious) that may lead to a low-speed or high-speed rejected takeoff Other cockpit effects / malfunctions (genuine or spurious) occurring during takeoff roll Runway incursion Wildlife incursion Bird strike	Excessive taxi speed Inadequate technique for line-up or 180-degree turn on runway Inadequate engine stand-up technique Gross error in takeoff weight entry and/or in V_1 / V_R speeds assessment Incorrect stab-trim setting Undetected incorrect takeoff configuration Late rejected takeoff decision / initiation Premature rotation (i.e., below V_R) Late rotation (i.e., above V_R) Slow rotation (i.e., low pitch rate) Low pitch attitude after lift-off	Note 2	Industry prevention strategies and best practices (Note 2) Adherence to SOP's (task sharing, briefings, use of checklists, standard calls and excessive-deviation callouts, mutual crosscheck and backup) Cross-check of takeoff data : weight-and-balance, stab-trim setting, fuel distribution, runway conditions, wind component, outside air temperature, corrections (QNH, air conditioning, anti-ice, …) flaps setting, V_1 / V_R speeds, assumed temperature / reduced or full thrust setting, ... Awareness of prevailing takeoff performance-limiting factor (available acceleration-stop distance or other limitation) Compliance with "minimum turn-around time", as applicable, to ensure adequate brakes energy Takeoff briefing highlighting the specific / non-routine aspects of the takeoff Line-up technique Readiness for possible stop or go scenarios (being go-minded whenever warranted) Enhanced monitoring and cross-check Effective wildlife / bird control program Effective runway maintenance program for periodic rubber-deposit removal

Incidents Accidents	Precursors		Risk Factors	Defenses / Controls
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
CFIT	GPWS / TAWS alert / warning (genuine or spurious) MSAW warning Other cases of reduced terrain separation Prolonged loss of communications (PLOC) between pilot and controller(s) Low-energy state during approach Land short (runway undershoot) event Low altitude pattern following a go-around Inappropriate low altitude maneuvering Low-on-fuel condition / fuel starvation	Low pitch attitude / shallow flight path / altitude loss after lift-off Flight below desired profile path during climb Lateral deviation during climb (SID) Descent / flight below segment or sector safe altitude Altimeter setting error Failure to check navigation accuracy before approach Lateral deviation during approach (STAR) Failure to revert to navaids raw data in case of doubts on automation Incorrect or inappropriate radar vectoring by ATC (i.e., below MVA and/or toward high terrain) Premature descent to the next step-down altitude during a multiple-steps-down non-precision approach DME confusion (non-collocated DME versus ILS-DME), in identifying the final descent point Premature descent to DA(H) before G/S intercept or premature descent to MDA(H) before final-descent-point / FAF Premature descent below MDA(H) before reaching the visual-descent-point (VDP) Flight below desired flight path during initial and/or final approach Continued approach, when below DA(H) or MDA(H), after loss of visual references Late or inadequate response to GPWS / TAWS alert / warning Late or inadequate response to MSAW warning Late or inadequate response to windshear warning Unstabilized approach (steep or shallow approach) Failure to go-around Lack of effective flight path control during go-around Failure to follow published missed-approach procedure Inadequate fuel management	Note 3	Industry prevention strategies and best practices (Note 3) Adherence to SOP's (task sharing, briefings, use of checklists, standard calls and excessive-deviation callouts, mutual crosscheck and backup) Cross-check of takeoff data : weight-and-balance, fuel distribution, wind component, runway conditions, flaps setting, V1 / VR speeds, ... Adherence to sterile-cockpit rule Adopting the constant-angle non-precision approach (CANPA) / constant-descent final-approach (CDFA) concept Use of an aircraft / airport-specific EOSID in case of engine failure Adequate use and supervision of automation Vertical and horizontal flight paths monitoring (situational and energy awareness) Altimeter setting cross-check Cross-checking cleared altitude versus minimum safe altitude Timely and adequate response to GPWS / TAWS alert or warning Timely and adequate response to MSAW warning Timely and adequate response to windshear alert or warning Awareness of minimum vectoring altitudes Awareness of approach design criteria (PANS-OPS versus TERPS) Awareness of relationship between track-distance to runway threshold and height (300 ft / nm rule-of-thumb) Awareness of low-OAT correction to be added to minimum approach altitudes / heights Awareness of minimum safe radio-altimeter readings for each approach segment (IAF-IF, IF-FAF) Awareness of " black-hole " or other visual illusions for prevailing approach Timely go-around Adherence to published missed-approach procedure Use of available aircraft technologies for enhanced situation awareness (vertical situation display, head-up display, enhanced-vision, …)

Incidents Accidents	Precursors		Risk Factors	Defenses / Controls
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Loss of Control **(In-flight)**	Gross loading error Cargo loading unsecured / shift Convective weather encounter Extreme turbulence encounter Extreme icing conditions encounter Windshear encounter Volcanic ash encounter Mountain wave / vortices encounter Wake turbulence encounter System failure affecting aircraft configuration, controllability and/or flying qualities System failure affecting the operation of primary instruments / displays or standby instruments Failures resulting in a non-standard fuel distribution Uncommanded thrust asymmetry In-flight smoke / fumes / fire (in cockpit, cabin, cargo) events that could affect the crew ability to conduct their duties and/or the aircraft controllability	Inadequate aircraft de-icing / anti-icing Premature flaps / slats retraction (pilot's lapse or control lever confusion) Aggressive maneuvering / overcontrolling Excessive pitch attitude Excessive bank angle Flight below maneuvering speeds Intentional or inadvertent approach to stall High-altitude flying with low buffet-margin (excessive altitude and/or mach number for prevailing gross-weight and turbulence conditions) Excessive response to TCAS orders Inadequate recovery from aircraft upset (uncommanded pitch attitude or bank angle excursion) Low-energy state during descent and approach Inadequate response to stall warning, GPWS warning, low-energy alert (as applicable) Incorrect use of automation Go-around attempt after thrust reversers deployment Lack of effective pitch attitude and/or bank angle control during go-around Inappropriate low altitude maneuvering	<u>Note 4</u>	Industry prevention strategies and best practices (<u>Note 4</u>) Adherence to SOP's (i.e., task sharing, briefings, normal checklists, standard calls and excessive-deviation callouts, mutual crosscheck and backup) Awareness of active meteorological threats along the route Cross-check of takeoff data : weight-and-balance, fuel distribution, wind component, runway conditions, flaps setting, V_1 / V_R speeds, ... Adherence to de-icing / anti-icing holdover times and clean-wing concept Awareness of visual illusions (e.g., black hole effect) or sensorial (somatogravic) illusions that may cause spatial disorientation after takeoff or go-around Alertness for recognition of and recovery from unusual attitudes Adequate use and supervision of automation Alertness to change-over PF / PNF roles in case of loss of PF flight instruments / displays Alertness to revert to standby instruments in case of total loss of captain and first officer primary instruments / displays Alertness to recognize and respond to an unreliable airspeed indication Alertness for the detection and avoidance of any severe weather area Management of buffet-margin at high altitude Adherence to maneuvering speeds Timely application of abnormal / emergency procedures when controllability or flying qualities may be affected Timely and adequate response to an overspeed / Mach number buffet onset condition Timely and adequate response to predictive windshear alerts and reactive windshear warning Timely and adequate response to low-energy alert (as applicable) and to stall warning Emphasized training on the conduct of smoke procedures (e.g., smoke removal) and emergency descent Understanding the leading fundamentals of flight dynamics over the entire flight regime

Incidents Accidents	**Precursors**		**Risk Factors**	**Defenses / Controls**
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Midair Collision	TCAS RA events (genuine or spurious) Airspace infringement Other cases of loss of separation Prolonged loss of communications (PLOC) between pilot and controller Failures affecting TCAS operation	Callsign confusion Altitude deviation Level bust (pilot lapse or late re-clearance by ATC) Airspeed in excess of 250 kt, when below FL 100 Failure to comply with an altitude or speed restriction / constraint Incorrect altimeter setting Navigation deviation Inappropriate visual avoidance maneuver Late and/or inadequate response to TCAS orders Inadequate ATC instruction or vectoring Inadequate coordination between ATM centers and/or ATC sectors Lack of English proficiency	Note 5	Industry prevention strategies and best practices (Note 5) Callsign deconflicting program Adherence to SOP's (i.e., task sharing, briefings, standard calls and excessive-deviation callouts, mutual crosscheck and backup) Adherence to sterile-cockpit rule Adherence to first operations golden rule (i.e., Fly, Navigate, Communicate, Manage, … in that order) Adequate use and supervision of automation Effective management of interruptions and distractions Effective pilot / controller communications (i.e., English proficiency, readback / hearback of ATC instructions, …) Active listening of ATC and other aircraft communications Vertical / lateral position awareness / monitoring Use of enroute strategic lateral offset procedure (SLOP) in trans-oceanic and/or remote continental airspace Reducing V/S when reaching cleared altitude / FL Operational understanding of "Maintain V/S", "Adjust V/S" and "Monitor V/S" TCAS messages Awareness of inhibition of TCAS RA sub-modes under given conditions Timely and adequate response to TCAS orders (with precedence over conflicting ATC instruction, if any, or own perception), and return to initial clearance when clear-of-conflict Alertness to respond to TCAS order reversal Enhanced lookout during visual approaches Use of available ground-based and aircraft technologies (ADS-B, …)

Incidents Accidents	Precursors		Risk Factors	Defenses / Controls
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Turbulence Encounter **(Injuries)**	System failures affecting weather radar operation Convective weather encounter Clear air turbulence encounter Mountain wave / vortices encounter Wake turbulence encounter	Inappropriate dispatch with weather radar unserviceable Inaccurate or outdated weather forecast information Inadequate use of weather radar (tilt, gain) or incorrect interpretation of weather picture Insufficient weather cell avoidance Inadvertent or inappropriate storm penetration Inadequate recovery from turbulence upset (load factor excursion, overspeed) Inadequate traffic separation (wake turbulence encounter)	Note 6	Industry prevention strategies and best practices (Note 6) Adherence to SOP's (i.e., task sharing, briefings, standard calls and excessive-deviation callouts, mutual crosscheck and backup) Adherence to cabin SOP's and safety procedures Use of most recent information on current and forecast weather conditions Availability of wind shear rate (SR in kts / 1000 ft) along the route and at planned or likely cruise FL Optimum use of weather radar for effective weather avoidance Management of high-speed and low-speed buffet margins for prevailing conditions (i.e., altitude / FL for given gross-weight, Mach number and turbulence conditions) Alertness for timely recovery of an overspeed condition Alertness for timely recognition of and recovery from an aircraft upset Use of airborne technologies for enhanced weather detection and avoidance, (e.g., 3-D multiscan weather radar, weather radar with enhanced turbulence mode, automatic uplink and display of turbulence PIREPS sent by preceding aircraft, …)

Incidents Accidents	Precursors		Risk Factors	Defenses / Controls
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Runway Excursion or Overrun **(Landing)**	Continued unstabilized approach (failure to comply with go-around criteria and policy) Tailwind or crosswind landing with tailwind and/or crosswind component(s) in excess of applicable limit(s), either intentionally or unknowingly Hard landing Bounced landing Deep (long) landing Temporary loss of directional control during rollout System failures that may affect braking devices (ground spoilers, brakes / autobrake, thrust reversers) System failures that may affect directional control (brakes, thrust reversers, nose wheel steering)	Descent above desired descent profile High energy approach due to lack of adequate planning or due to challenging design of STAR (high fix-crossing-altitudes, …) or challenging ATC instructions (late descent, vectors, altitude or speed restrictions, …) Late deceleration and configuration set-up for approach and landing DME / ILS DME confusion in assessing the final descent point / FAF Unstabilized final approach (high, fast, steep, …) Tailwind component above limit Failure to remember / assess crosswind component limit for prevailing runway condition Failure to arm ground-spoilers Inappropriate selection of autobrake mode for given runway length and condition Failure to go-around, when so required Late thrust reduction or power-on touchdown Inappropriate continuation of landing after bounce Inadequate bounce recovery technique Inadequate crosswind landing / decrab technique Long / floating flare Touchdown off centerline Long derotation Delayed selection of reverse thrust Inappropriate use of differential reverse thrust Late activation of pedal braking or takeover from autobrake, when so required Inadequate use of differential braking Use of nose wheel steering tiller during rollout Vacating runway at excessive speed for given turn-off angle and surface condition	Note 7	Industry prevention strategies and best practices (Note 7) Awareness of relevant NOTAMs (work-in-progress / displaced threshold, …) Awareness of runway remaining lighting and/or signage at destination airport Adherence to SOP's (task sharing, briefings, use of checklists, standard calls and excessive-deviation callouts, mutual crosscheck and backup) Operating recommendations for severe convective weather avoidance in terminal area Monitoring of descent profile (FMS, rule-of-thumb) Energy state awareness and management Awareness of possible visual illusions for landing runway Adherence to stabilized approach concept Strict adherence to standard calls and excessive-deviation callouts Adherence to go-around policy Readiness to go-around if visual references are lost when below DA(H) or MDA(H) Timely go-around decision Enhanced monitoring by PNF (PM) Information by ATC on runway condition and/or braking action and of any change thereof Awareness of and accounting for the combined effect of all factors affecting the final approach speed and landing distance for prevailing airfield and runway condition Assessment of landing distance, for prevailing airfield / runway conditions, prior to each landing Adherence to bounce recovery policy and procedure

Incidents Accidents	Precursors		Risk Factors	Defenses / Controls
Hazards (Risk Domains)	**Occurrences (Uneventful Events)**	**Deviations (Procedural / Flight Path)**	Threats	Prevention Detection / Recovery
Wildlife Threat	Wildlife incursion Bird flock encounter	Note 8	Note 8	Note 8
Cabin Safety	Note 9	Note 9	Note 9	Note 9
Ramp Safety	Note 10	Note 10	Note 10	Note 10

In addition to the documents referenced in **Notes 1** thru **10** below, recommendations for the prevention and mitigation of the above hazards are also published in the ICAO / industry-developed document titled **Implementing the Global Aviation Safety Roadmap** (Appendices E, F and G).

Note 1 :

Risk factors (threats) that may contribute to ground collisions (as well as related prevention strategies and best practices) are identified in the following industry-developed documents :

- European Action Plan for the Prevention of Runway Incursions (EAPPRI);
- ICAO, US FAA, IATA, … Runway Incursions Prevention Programs;
- ALPA International – Runway Incursion – A Call for Action (White Paper) – March 2007;
- Airbus Flight Operations Briefing Notes (FOBN) – Runway and Surface Operations section - Preventing Runway Incursions; and,
- NLR Report NLR-CR-2006-149.

Note 2 :

Risk factors (threats) involved in runway excursions / overruns at takeoff (as well as associated prevention strategies and best practices) are identified in the following industry documents :

- FAA / Industry – Takeoff Safety Training Aid (and associated Rejected Takeoff video).
- Flight Safety Foundation – ALAR Toolkit :
  - ALAR Risk Awareness Tool (RAT);
  - ALAR Risk Reduction Guide (RRG); and,
  - ALAR Briefing Notes.

- Flight Safety Foundation / IATA – Runway Safety Toolkit :
    - Report on Runway Safety Initiative – Sections 4 and 5; and,
    - Runway Excursion Risk Awareness Tool (RERAT);
- Airbus – Flight Operations Briefing Notes – Takeoff and Departure Operations section.

Note 3 :

Risk factors (threats) observed in controlled flight into terrain – CFIT - events (as well as recommended prevention strategies and best practices) are identified in the following documents :

- FAA / Industry – CFIT Education and Training Aid :
    - CFIT Checklist – Evaluate the Risk and Take Action.
- Flight Safety Foundation – ALAR Toolkit :
    - ALAR Risk Awareness Tool (RAT);
    - ALAR Risk Reduction Guide (RRG); and,
    - ALAR Briefing Notes.
- Airbus Flight Operations Briefing Notes – Operating Environment section – Enhancing Terrain Awareness.

Note 4 :

Risk factors (threats) that could contribute to loss-of-control in flight (as well as prevention strategies and best practices) are identified in the following industry document :

- The Airplane Upset Recovery Training Aid (Revision 2, or subsequent revisions).

Note 5 :

Risk factors (threats) that may contribute to a midair collision (as well as proven prevention strategies and best practices) are identified in the following Eurocontrol documents :

- Level Bust Toolkit;
- Air / Ground Communication Toolkit; and,
- ACAS II Safety Bulletins.

Note 6 :

Risk factors (threats) observed in turbulence encounters, as well as avoidance strategies and best practices, are identified in the following industry documents :

- FAA / ATA / Boeing – Turbulence Education and Training Aid;
- McDonnell Douglas – Wake Turbulence Training Aid; and,
- Airbus – Flight Operations Briefing Notes – Adverse Weather Operations and Cabin Operations sections.

Note 7 :

Risk factors (threats) related to runway excursion / overrun at landing (as well as prevention strategies and best practices) are identified in the following industry documents :

- Flight Safety Foundation – ALAR Toolkit :
  - ALAR Risk Awareness Tool (RAT);
  - ALAR Risk Reduction Guide (RRG); and,
  - ALAR Briefing Notes;
- Flight Safety Foundation / IATA – Runway Safety Toolkit :
  - Report on Runway Safety Initiative – Sections 4 and 5; and,
  - Runway Excursion Risk Awareness Tool (RERAT);
- NLR Report – NLR-CR-2006-149.

Note 8 :

Risk factors (threats) related to wildlife threat are identified in the following documents :

- Sharing the Skies – An Aviation Industry Guide to the Management of Wildlife Hazards (reference Transport Canada - TP 13549 E); and,
- Aerodrome Bird Hazard Prevention and Wildlife Management Handbook – Airport Council International (ACI).

Note 9 :

Risk factors (threats) that may affect cabin safety (as well as prevention strategies and best practices) are identified in the following industry documents :

- GAIN - Cabin Safety Compendium;
- IATA - Cabin Safety Toolkit; and,
- Airbus brochure Getting to Grips with Cabin Safety, and associated Cabin Operations Briefing Notes.

Note 10 :

Risk factors (threats) that may influence ramp safety are identified in the following Flight Safety Foundation resource :

- Ground Accident Prevention Program :
  - http://flightsafety.org/archives-and-resources/ground-accident-prevention-gap.

Appendix 2

Implicit Operating Safety Models

(Compiled by author – 1995 - 2010)

Risk Domains	Defenses / Controls	Safety Models - Sources
All	Basic Elements of Airmanship	**Air France** Bulletin de Sécurité des Vols - No. 27 - Circa 1993 Bulletins de Sécurité des Vols - No. 33 - 1995 and No. 46 - 2000 **Anthony T. Kern** Redefining Airmanship - 1997 **New Zealand CAA** Vector bulletins - 2001 thru 2003 **FSF - ALAR Toolkit** ALAR Briefing Note 1.3 - Operations Golden Rules **Operational Guide to Human Factors in Aviation** http://www.skybrary.aero/index.php/Portal:Human_Factors or http://www.skybrary.aero/index.php/Portal:OGHFA
All	Operations Golden Rules	**FSF - ALAR Toolkit** ALAR Briefing Note 1.3
All	Training standards	**International / National Training Standards** PPL, CPL and ATPL / MPL **Manufacturers' and Operators' Training Standards** Operating / Training Manuals and Training Courseware's
All	Crew Resource Management (CRM)	**Manufacturer's and Operator's CRM courses** **FSF - ALAR Tool Kit** ALAR Briefing Notes 2.1 thru 2.4 - Crew Coordination **Operational Guide to Human Factors in Aviation** http://www.skybrary.aero/index.php/Portal:OGHFA **US FAA Advisory Circulars** AC 60 - 22 - Aeronautical Decision Making AC 120 - 51E - Crew Resource Management Training

Risk Domains	Defenses / Controls	Safety Models - Sources
All	Operating Standards	**Manufacturer's and Operator's SOPs** **FSF - ALAR Toolkit** Briefing Notes 1.1 thru 1.6 and 2.1 thru 2.4 SOP's template **US FAA - Advisory Circulars** AC 91- 73, AC 120 - 71A and AC 120 - 74A **Manufacturer's and Operator's Non-normal Procedures**
All	Use of Automation	**Manufacturer's and Operator's Operating and Training Manuals** SOP's - Introduction Automation Policy **FSF - ALAR Toolkit** ALAR Briefing Note 1.2 and 1.3 **US Commercial Aviation Safety Team (CAST)** Safety Enhancement 30 (SE - 30) Recommendations for an Automation Policy
All	Pilot / Controller Communications	**FSF - ALAR Toolkit** ALAR Briefing Note 2.3 **Eurocontrol - AGC Toolkit** Air / Ground Communication Toolkit **Global Aviation Information Network (GAIN)** Reports on Working Group E http://flightsafety.org/archives-and-resources/global-aviation-safety-network-gain
All	Errors Management	**Threat-and-Error Management (TEM) model** Error Management markers
All	Threats Management	**Threat-and-Error Management (TEM) model** Threat Management markers

Risk Domains	Defenses / Controls	Safety Models - Sources
Altitude Deviation Level Bust	Threat-related Prevention Strategies	**Eurocontrol - European Air Traffic Management Program** http://www.eurocontrol.int/eatmp and http://www.eurocontrol.int/safety Level Bust Safety Bulletins **IATA / Eurocontrol - Level Bust Tool Kit** European Action Plan for the Prevention of Level Bust Level Bust Briefing Notes **FSF - ALAR Toolkit** ALAR Briefing Notes 3.1 and 3.2
Approach-and- Landing Accidents	Threat-related Prevention Strategies	**FSF - ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Briefing Notes - Chapters 1 thru 8 ALAR Risk Awareness Tool (RAT) ALAR Risk Reduction Guide (RRG) **Airbus – Brochure Getting to Grips with** … Approach-and-Landing Accidents Reduction **Commercial Aviation Safety Team (CAST)** Results and Analysis Problem Statements and Interventions Characteristics / Indicators Master Collector **Global Aviation Information Network (GAIN)** http://flightsafety.org/archives-and-resources/global-aviation-safety-network-gain
Cabin Smell Smoke / Fumes Fire	Threat-related Prevention Strategies	**Manufacturer's / Operator's Operating Manuals / Courseware's** (Flight Crew / Cabin Crew) **Global Aviation Information Network (GAIN)** http://flightsafety.org/archives-and-resources/global-aviation-safety-network-gain Cabin Safety Compendium **FSF - Smoke / Fire / Fumes Project** Industry Task Force report Template for Smoke / Fire / Fumes procedures **Airbus - Cabin Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Cabin Smoke Awareness

Risk Domains	Defenses / Controls	Safety Models - Sources
CFIT	Threat-related Prevention Strategies	**FSF / FAA - CFIT Education and Training Aid** CFIT Checklist - Evaluate Risk and Take Action **FSF - ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Risk Awareness Tool – RAT ALAR Risk Reduction Guide – RRG ALAR Briefing Note 5.2 - Terrain Awareness ALAR Briefing Note 6.3 - Terrain Avoidance - Pull-up - Maneuver **Airbus - Brochure Getting to Grips with …** Approach-and-Landing Accidents Reduction **Commercial Aviation Safety Team (CAST)** Results and Analysis Problem Statements and Interventions Characteristics / Indicators Master Collector
Ground Collision	Threat-related Prevention Strategies	**ICAO** Manual on the Prevention of Runway Incursions (Doc. 9870 – AN / 463) Runway Safety Toolkit **Eurocontrol-led Industry Action Plan** European Action Plan for the Prevention of Runway Incursions (EAPPRI) **Eurocontrol** Airport Operations Program **US FAA / IATA / PAAST** Runway Incursion Prevention Programs Education and Training Aids **Commercial Aviation Safety Team (CAST)** Results and Analysis Problem Statements and InterventionsCharacteristics / Indicators Master Collector **Transport Canada** National Civil Aviation Safety Committee Sub-Committee on Runway Incursions Final Report Reference TP 13795 E - Sept.14/2000 **Flight Safety Foundation** Airport Operations Bulletins (Jul.-Aug. 2000, Nov.-Dec. 2001, Jul.-Aug.2003) **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Runway and Surface Operations section : Preventing Runway Incursions

Risk Domains	Defenses / Controls	Safety Models - Sources
Lateral Deviations Navigation Error	Threat-related Prevention Strategies	**UK CAA** North Atlantic MNPS Airspace Operations **FSF - ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Briefing Note 1.2 - Optimum Use of Automation ALAR Briefing Note 1.3 - Operations Golden Rules
Loss of Control (in flight)	Threat-related Prevention Strategies	**Industry Task Force** The Airplane Upset Recovery Training Aid **US Commercial Aviation Safety Team (CAST)** Results and Analysis Problem Statements and Interventions Characteristics / Indicators Master Collector
Midair Collision	Threat-related Prevention Strategies	**Eurocontrol** European Air Traffic Management Program (EATMP) http://www.eurocontrol.int/eatmp and //www.eurocontrol.int/safety Level Bust Safety Bulletins Level Bust Prevention Toolkit Air / Ground Communication Toolkit ACAS II Bulletins (http://www;eurocontrol.int/acas/) ACAS Brochure - WP-6.1 - ACASA/WP6.1/015 ACAS II Operations in the European RVSM ACAS Training Tool RITA (Replay Interface for TCAS Alerts) Airspace Infringement Initiative **FSF - ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Briefing Notes 1.1, 1.3, 2.3, 2.4, 3.1 and 3.2

Risk Domains	Defenses / Controls	Safety Models - Sources
Ramp Safety / Ramp Damage	Threat-related Prevention Strategies	**Flight Safety Foundation** Ground Accident Prevention Program http://flightsafety.org/archives-and-resources/ground-accident-prevention-gap
Runway Excursion / Overrun (Landing)	Threat-related Prevention Strategies	**FSF - ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Risk Awareness Tool – RAT ALAR Risk Reduction Guide – RRG ALAR Briefing Notes 8.1 thru 8.7 **FSF / IATA Runway Safety Toolkit** http://flightsafety.org/current-safety-initiatives/runway-safety-initiative-rsi Report on the Runway Safety Initiative Runway Excursion Risk Awareness Tool - RERAT **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Landing Techniques section
Runway Excursion / Overrun (Takeoff)	Threat-related Prevention Strategies	**FAA / Industry - Takeoff Safety Training Aid** (Training Aid and Video) (Manufacturer-specific Annexes) **FSF ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Risk Awareness Tool - RAT ALAR Risk Reduction Guide - RRG ALAR Briefing Note 8.1 - Preventing Runway Excursion and Overrun **FSF / IATA Runway Safety Toolkit** http://flightsafety.org/current-safety-initiatives/runway-safety-initiative-rsi Report on the Runway Safety Initiative Runway Excursion Risk Awareness Tool - RERAT **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Takeoff and Departure Operations section : Revisiting the "Stop or Go" Decision Understanding the Takeoff Speeds Supplementary Techniques section : Handling Engine Malfunction

Risk Domains	Defenses / Controls	Safety Models - Sources
Runway Incursion (Ground Collision)	Threat-related Prevention Strategies	**ICAO** Manual on the Prevention of Runway Incursions (Doc. 9870 – AN / 463) Runway Safety Toolkit **Eurocontrol / Industry** European Action Plan for the Prevention of Runway Incursions (EAPPRI) **US FAA** Runway Safety Program **FAA / IATA / PAAST** Runway Incursion Prevention Programs Education and Training Aids **Commercial Aviation Safety Team (CAST)** Results and Analysis Problem Statements and Interventions Characteristics / Indicators Master Collector **Transport Canada** National Civil Aviation Safety Committee Sub-Committee on Runway Incursions Final Report Reference TP 13795 E - Sept.14/2000 **Flight Safety Foundation** Airport Operations Bulletins (Jul.-Aug. 2000, Nov.-Dec. 2001, Jul.-Aug.2003) **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Runway and Surface Operations section : Preventing Runway Incursions Conducting Effective Briefings **ALPA International** Runway Incursions - A Call for Action (White Paper - March 2007)
Turbulence (Wake)	Threat-related Prevention Strategies	**FAA / ATA / Boeing** Turbulence Education and Training Aid **Mc Donnell / Douglas** Wake Turbulence Training Aid **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Operating Environment section : Wake Turbulence Awareness / Avoidance

Risk Domains	Defenses / Controls	Safety Models - Sources
Turbulence (Weather)	Threat-related Prevention Strategies	**FAA / ATA / Boeing** Turbulence Education and Training Aid **Mc Donnell / Douglas** Wake Turbulence Training Aid **Commercial Aviation Safety Team (CAST)** Results and Analysis Problem Statements and Interventions Characteristics / Indicators Master Collector **Manufacturer's and Operator's Operating and Training Manuals** Inclement Weather / Adverse Weather Operation **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Adverse Weather Operations section : Optimum Use of Weather Radar Cabin Operations section : Turbulence Threat Awareness
Volcanic Ash	Threat-related Prevention Strategies	**Manufacturer's and Operator's Operating and Training Manuals** Inclement Weather / Adverse Weather Operation **Airbus * Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Operating Environment section : Volcanic Ash Awareness
Wildlife Hazards	Threat-related Prevention Strategies	**Transport Canada** Sharing the Skies An Aviation Industry Guide to the Management of Wildlife Hazards Reference TP 13549 E **Airport Council International (ACI)** http://www.aci-safetynetwork.aero Aerodrome Bird Hazard Prevention and Wildlife Management Handbook

Risk Domains	Defenses / Controls	Safety Models - Sources
Windshear	Threat-related Prevention Strategies	**FAA / Industry** Windshear Education and Training Aid **Manufacturer's and Operator's Operating and Training Manuals** Inclement Weather / Adverse Weather Operations Operation in Windshear / Downburst Conditions **FSF - ALAR Toolkit** http://flightsafety.org/current-safety-initiatives/approach-and-landing-accident-reduction-alar ALAR Briefing Note 5.4 - Windshear Awareness **Airbus - Flight Operations Briefing Notes** http://www.airbus.com/en/corporate/ethics/safety_lib/ Adverse Weather Operations section : Windshear Awareness Optimum Use of Weather Radar

Appendix 3

Challenged Operating Assumptions

(Compiled by author – 1995 - 2010)

The table below provides a categorized list of implicit operating assumptions that have been challenged in one or more in-service occurrences analyzed by the author (uneventful events, incidents or accidents), regardless of the type of equipment (make and model) and operation.

This sample list is far from being exhaustive; it could be further expanded by formulating all the operating assumptions that may be derived from the individual safety models listed in the **Appendix 2**.

Domain	Operating Assumptions
Policies	The operator has a published policy encouraging initiating a go-around in case of an unstabilized approach or in case of loss of visual references, when below DA(H) or MDA(H)
	The operator has a published policy for the conduct by junior first officers of crosswind landings and approach-and-landing under challenging weather or airport conditions
Safety Awareness	The operator uses risk assessment tools to assess the individual threats and hazards associated with operations to / from each individual airport or along each individual company route and related airspace
	Flight crew members are aware of the various industry-developed education and training aids / toolkits and have access to them or to their adaptation by the company
Airmanship	Flight crew members adhere to the basic elements of airmanship, acquired during their basic training and developed further on during their flying career
	Flight crew follows the " plan / execute / verify " operating best practice
	Flight crew monitors the pitch attitude and bank angle and keep them within safe operating limits
	Flight crew defines successive " target / windows " along the entire flight profile, as well as objectives (e.g., position, altitude, airspeed, configuration, vertical speed or flight path angle, power setting, …) to be achieved when reaching the next target / window Flight crew monitors that the defined objectives will be achieved, or anticipates the corrective action(s) required to achieve these objectives (i.e., flight path and energy management)
	Flight crew is alert to recognize a high-energy approach and to take action (e.g., use of speed brakes, early extension of landing gear, requesting a delaying vector, …) to recover a normal energy-state and the intended flight-path
	Flight crew does not apply excessive controls inputs (over-controlling)

Domain	Operating Assumptions
	Flight crew is aware of rules-of-thumb and safe flight parameters that allow to " fly by the numbers ", if so required
	Flight crew is aware of the relationship between " pitch / power / performance " for various flight phases
	Flight crew is prepared for and alert to respond to the most probable context-related or flight-phase-related contingency scenario
	Flight crew does not interfere intentionally with aircraft systems
	Flight crew understands the flight dynamics of high-altitude flying and its operational implications (e.g., low-speed and high-speed buffet onset, buffet-margin, …)
	Flight crew and controllers effectively adhere to the " read-back, hear-back " principle
	Flight crew checks any new FL / altitude clearance against the applicable segment / sector minimum safe altitude
Training	Flight crew actions are not unduly delayed and are performed with a response time consistent with the criticality of the action (i.e., normal, abnormal or emergency conditions)
	Flight crew applies abnormal and emergency procedures " as trained "
	Flight crew has an operational understanding of systems engagement / disengagement pre-conditions and logics (i.e., activation / deactivation, extension / retraction, …)
	Flight crew has sufficient knowledge and operational understanding of individual systems and of their interfacing, in order to manage situations that may be at the boundary or beyond the scope of published procedures
	Flight crew is alert to and trained for conducting a go-around from any point during the approach and landing (i.e., considering an early go-around for runway occupancy, a go-around at minimums or a late go-around following the loss of visual references, a long landing or a bounce)
	Flight crew is aware of the aircraft deceleration capability in level flight (i.e., from clean to approach flaps configurations) and on a 3-degree flight path (i.e., from approach to landing flaps configurations)
	Flight crew is aware of the typical flight parameters (pitch attitude, thrust setting) that ensure safe flight (i.e., during climb, level flight or descent)
	Flight crew understands the operation of various autobrake modes (i.e., time delays, pre-set deceleration rates) and the resulting autobrake operation on dry or contaminated runway (with reference to the applicable aircraft operating manual and to the ALAR Briefing Note 8.5)
	Flight crew understands the use of all cockpit controls in the context of normal, abnormal and emergency procedures

Domain	Operating Assumptions
	Transition training recalls the elements of basic airmanship and how to carry them over when transitioning to a new type
	When selecting a system or when setting a target value, the flight crew ensures that the correct selector / control is used and is actuated in the intended manner
SOP's	Flight crew strictly adheres to company SOP's, including task sharing, briefings, use of normal checklists, standard calls and excessive-deviation callouts, mutual crosscheck and backup
	Systems are always armed, engaged, used and monitored as per SOP's (e.g., automation, ground spoilers, autobrake, thrust reversers, …)
	Flight crew and cabin crew strictly adhere to the sterile cockpit rule, but cabin crew is aware of circumstances that warrant breaking this rule
	Flight crew maintains overall situation awareness during cruise by periodically reviewing systems operation on corresponding display unit
	Flight crew monitors FMS navigation, particularly during SID and STAR phases of flight
	Load-and-trim sheet is checked by both the dispatcher and the flight crew for possible gross errors
	Operating guidelines are available to support the flight crew's "stop-or-go" decision during the various phases of the takeoff roll (i.e., below or above 100 kt)
CRM	Coping strategies are available for the management of distractions and interruptions
	Coping strategies are available for the recall of actions that have been delayed from their normal time-sequence or location in the normal flow of SOP's actions
	CRM best practices always allow the timely detection and recovery of monitoring errors and working errors
	Mutual crosscheck and back-up allow the detection of omissions, action slips, entry errors and/or untimely / inappropriate actions
	PF always acknowledges PNF (PM) excessive-deviation callouts and confirms his/her intentions for corrective action(s)
	PNF (PM) always monitors the PF effectively
	The effects of workload and/or fatigue can always be mitigated by strict adherence to SOP's and to CRM best practices
Automation	Flight crew uses automation as per company SOP's / automation policy

Domain	Operating Assumptions
	Flight crew is aware of operating recommendations for the engagement, use and supervision of automation
	Flight crew does not engage the auto-pilot if flight-director orders are not followed while hand-flying the aircraft (i.e., if flight-director command bars are grossly off-center)
	Flight crew uses the primary flight display and navigation display as prime references to monitor the status of auto-pilot and auto-throttle / auto-thrust modes (i.e., modes armed or engaged) and active guidance targets (i.e., altitude, vertical speed or flight path angle, airspeed or Mach number, heading or track)
	Auto-pilot and auto-throttles / auto-thrust active and armed modes, set guidance targets are monitored at all times
	Flight crew is aware, at any time, of the association (pairing) of autopilot and auto-throttle / auto-thrust modes (i.e., awareness of what the elevator is controlling and of what the thrust is controlling)
	Flight crew understands the sequences of auto-pilot and auto-throttles / auto-thrust modes transitions, as a result of the modes previously armed or engaged and set guidance targets
	SOP's standard calls include the callout of any mode change as well as the callout of any change of guidance target, as indicated on the respective annunciations and scales of the primary flight display and navigation display
	Flight crew always verifies FMS entries for reasonableness
	Flight crew " cleans " the FMS flight plan (F-PLN) to ensure that the TO waypoint is ahead of the aircraft
	Flight crew maintains a realistic FMS flight plan (F-PLN), when under radar vectoring, in readiness for re-engaging NAV mode
	Flight crew monitors FMS navigation (i.e., correct TO waypoint, correct sequencing of waypoints and correct navigation after waypoint crossing)
Flight Information	Instrument approach charts are designed in such a way as to prevent the confusion between a non-collocated VOR-DME and the runway ILS-DME, in the identification of the final descent point
Weather Information	Adverse weather forecast (windshear, convective weather, clear air turbulence, icing conditions, …) is available at departure and is updated while enroute
	Flight crew is aware that the wind reading provided by the tower controller may be either an averaged wind or an instantaneous wind, depending on airport equipment
	Flight crew is informed of runway condition (nature and depth of contaminant and/or braking action) and of any change thereof during the approach
	Flight crew understands the differences between the wind values provided by the TAF / METAR reports, ATIS message, IRS / FMS and tower controller, and of their respective significance at the various stages of the approach

Domain	Operating Assumptions
	Operating recommendations are available for adverse weather avoidance
	Operating recommendations are available for the optimum use of the weather radar and for the interpretation of the weather contours and details (e.g., cues of likely severe / extreme weather, possible areas of weather display attenuation, …)
	Wind direction, velocity and gustiness near touchdown zone is always available (i.e., at each airport and for each runway)
Performance Data	Flight crew is aware of the combined effects of prevailing airfield and runway conditions on the final approach speed and landing distance (e.g., airfield elevation, non-standard approach path angle, …, crosswind / tailwind components, runway condition, …)
	Flight crew knows the maximum crosswind component for each runway condition
	Landing performance data are available in a format that is consistent with the information available regarding the runway condition (nature and depth of contaminant and/or braking action)
	Takeoff and landing performance data account for any relevant inoperative item (MEL / DDG) or missing airframe item (AFM / CDL)
Go-around Decision	Flight crew is go-around-minded and go-around-prepared
	The elements of a stabilized approach are known and a go-around is initiated if the approach is not stabilized when reaching the minimum stabilization height (usually, 1000 ft in IMC and 500 ft in VMC)
	Flight crew initiates a go-around if visual references are lost, at any time, when below DA(H) or MDA(H)
	Flight crew initiates a go-around if the approach becomes grossly de-stabilized when below the stabilization height
	Flight crew initiates a go-around if the aiming point moves beyond the touchdown zone
Abnormal / Emergency Condition	Flight crew does not apply electronic or paper checklists " blindly " but validates the relevance of actions as well as their pre-conditions before acting
	Flight crew always observes the result of an action before moving to the next one (i.e., understand … act … verify)
	Flight crew does not recycle a circuit breaker or reset a system, unless this is documented in the aircraft operating manual and/or quick-reference handbook
	Flight crew understands the concept of Advisory condition and the associated guidelines for monitoring-only or for action

Domain	Operating Assumptions
	Flight crew always performs electronic or paper checklist procedures in the intended sequence and completely
	In any circumstance, but particularly in case of an abnormal or emergency condition, the flight crew adheres to the first golden rule of safe operation : " Fly, Navigate, Communicate, Manage, … in that order "
	Operating recommendations (e.g., golden rules, decision making models, …) are available for the management of situations that may be at the boundary or beyond the scope of published procedures
	Flight crew identifies the applicable procedure(s) and action(s) based on activated alerts and/or other cockpit effects, or based on the automatic activation of the electronic checklist
	Flight crew understands the strategy, phases (if any), pre-conditions and action steps of all abnormal / emergency procedures
	The need and way for coordinating several inter-linked abnormal / emergency procedures (as applicable) are clearly indicated to the flight crew
ATM / ATC	Pilots and air traffic controllers are aware of the risks of callsign confusion
	Air traffic controllers carefully hearback the pilots' readback and correct it as required
	Flight crew clearly reads back all the elements of a clearance / instruction … and challenges them if in doubt
	Pilot / controller communications are not blocked by simultaneous transmissions
	Air traffic controller assigns the most favorable runway for takeoff or landing, considering crosswind and/or tailwind components
	Air traffic controller does not assign a " FL ", after the aircraft has been cleared to an " altitude ", during descent (i.e., after altimeter setting change from STD to QNH)
	Standard arrivals (STAR's) are designed to ensure trajectories and fix-crossing-altitudes that are compatible with the preparation and conduct of a stabilized approach
	Air traffic controllers provide vectors, altitude restrictions and speed-control instructions that are always compatible with the preparation and conduct of a stabilized approach
	Air traffic controllers are aware of airliners deceleration characteristics (i.e., going down while slowing down dilemma)
	Air traffic controllers are aware of the need to reconfigure navaids and flight management systems in case of a late or last-minute runway change

Appendix 4

More Quotes about Prevention and Precursors

Quotes always are inspiring sentences that reflect the vision and wisdom of their authors ; often, quotes encapsulate all the leading fundamentals of the subject matter and, hence, offer precious information on how we can adopt and adapt these fundamentals.

Here are a few quotes, from great aviation safety leaders, about incident / accident prevention and about the identification, analysis and use of precursors.

About the need for an evolving prevention strategy

“ As the accident rate reduces, the opportunity to develop effective accident-investigation-derived recommendations for the industry is also reduced …

… A shift is needed to the investigation of incidents that have the potential to lead to an accident …

… Reduced accident rates, long periods without accidents, limited outcome of incidents, … result in minimizing the perception of risk and the need to learn from incidents …

… The shift to minimize the perceived potential of incident reflects a shift of defense and avoidance of blame within the organization …

… Culture slips back to view only the individual aspect of error or failure …

… A culture of perceived risk minimization and blame avoidance largely diminishes the desire to learn from incidents, suggesting cheap solutions that do nothing to prevent the next incident or accident …

… So, what do we need to change ? … We need to recognize the precursor nature of incidents and treat incidents as free lessons “.

Andrew Rose – Air Safety Week – Sept. 27/04

“ Industry has moved from an analysis of what has happened to an analysis of what the data show might happen with a certain degree of probability “.

Marion Blakey – FAA Administrator – 2002-2007

“ If we were to continue to put downward pressure on the accident rate, we need far more information about trends, about precursors, and about what is going on every day in the manufacturing, operating and maintenance environments “.

“ We want to push the science of advanced data analysis tools that will enable discovering vulnerabilities, reveal precursors of accidents, and permit to proactively take steps to mitigate risks before loss of life “.

Nick Sabatini – FAA Administrator – Address to ISASI – May 2006

“ We are seeing a disturbing set of accidents that seem to lack a common thread …

… As random as these recent accidents look, though, one factor does connect them; we didn’t see them coming and we should have ”

Bill Voss – President and CEO, Flight Safety Foundation – AeroSafety World journal – May 2009

“ The proactive part of safety management is in trend analysis and human factors investigation to identify why events occurred and where we are most at risk …

… Our next accident is only a combination of incidents away “.

Captain Roger Whitefield – Chief Air Safety Investigator – British Airways

" Instead of seeing humans as a source of risk, they should be seen as an indispensable resource of safety "

Erik Holnagel – presenting James Reason's book " Unsafe Acts, Accidents and Heroic Recoveries "

" By looking across all sectors, with a mixture of expertise, we minimize the potential for overlooking gaps in safety barriers ".

Michael Bell - UK CAA

" We failed to heed the data in a couple of ways "

Author unknown

" The data were there but were didn't find the implication in time "

Author unknown

" The role of prevention is to displace the holes in the error plates ".

Author unknown

About data reporting / collection / integration

" Integrations of data provide an early insight about safety issues, as they emerge around the world "

Bill Voss – President and CEO, Flight safety Foundation – AeroSafety World journal – September 2009

" I want to know about each and every near-miss ".

Captain Scott Schleiffer – IASS 2005

" We go where data send us ".

Captain Charlie Bergman – ALPA International

About identifying precursors (weak signals)

" Shifting from what has been a traditionally forensic aviation safety stand to one that is proactive in order to uncover issues that were in the noise before and occurring infrequently ".

Nick Sabatini - FAA Administrator – August 2007

" Predicting is important, but there is something always to be gained by remembering, as well "

Bill Voss – President and CEO, Flight safety Foundation – AeroSafety World journal – October 2008

" What is important is invisible to the eyes "

Antoine de Saint Exupéry – Le Petit Prince

" Making safety events and trends visible, understandable and usable, are the main challenges of any airline SMS ".

Captain Bertrand de Courville – Air France

“ Accident prevention begins with knowledge, insight and communication about events that occur on the line …

… By identifying links that cause chain-of-events reactions, we can raise our own level of consciousness and be more aware of traps that await all crewmembers “.

US Airway

“ It is increasingly accepted that accidents result from the insidious accumulation and interaction of many small failures, whether these be of equipment, personnel, procedures or the unanticipated consequences of automated processes “.

Captain Neil Johnston – Aer Lingus – 1996

“ As organizations, equipment and tasks become more complex and opaque to inspection and [to] the understanding of any one individual, we can expect increasingly esoteric and unexpected accident causal sequences “.

Perrow (1984) – James Reason (1990)

“ Most accidents are triggered by known but ignored compromises that became critical due to their cumulative effect in a foreseeable set of circumstances “

Gerard M. Bruggink – Former Deputy Director, Bureau of Accident Investigations – US NTSB

“ Analyzing precursors is looking at small tremors in order to warn of a possible major earthquake “.

Author unknown

“ The identification of precursors deals with threats that – if allowed to remain unnoticed and unaddressed – could eventually result in a major event or accident “.

Author unknown

About data analysis

“ Sustaining safety trends requires full knowledge of factors that contribute to accidents, including the interplay of human and technical factors, policies, procedures and environmental and safety culture factors …

… We need to answer the following questions :

- What happened ?
  - What are the facts ?
- How did it happen ?
  - What were the breached defenses / controls ?
- Why did it happen ?
  - What were the active and latent failures ?
- How to prevent the recurrence ?
  - What prevention strategies / interventions are available and effective ?

… Minimizing future risks is learning from the past “.

Charles H. Simpson – Acting Chairperson – Canadian TSB – 2005

“ The suggestion that corrective action is dependent upon the recovery of a trend or a pattern is misleading …

… Even one occurrence can establish a trend that demands immediate remedy “

Gerard M. Bruggink

“ In the problem lies the solution …

… You cannot fix a category of accidents, you can just fix the contributing factors …

… Assess what went wrong, what the crew did or did not do, and why ? …

… Formulate standard problem statements “.

Paul Russell – Boeing – CAST

“ We need to reach across boundaries to stop human error “.

Bill Voss – President and CEO, Flight Safety Foundation – AeroSafety World journal – April 2007

“ It is too much easy to criticize the benefit of insight, as no one can say that a different approach would have produced a different outcome “.

Author unknown

About challenging our operating assumptions

“ What went wrong ? … What went right ? … What could we do to make it better next time ? “

Captain Dick McKinney – USAF – American Airlines – FSF

“ There are no new ways to crash an airplane … just variations on the theme “.

Author unknown

“ In an effectiveness / reliability diagram, a domain must account for defense ineffectiveness or defense unreliability ”.

Foresythe

About using lessons learned

“ Advocating safety in this remarkable safe industry isn’t easy … It is tough to stand up every day and suggest fixes for problems that have not happened yet …

… It is even worse if you have to convince people to spend money on a risk that doesn’t seem real to them ”.

Bill Voss – President and CEO, Flight Safety Foundation – AeroSafety World journal – March 2008

“ Find the reasons, stop feeding the causes and let the reasons starve “.

Dr Robert O. Besco – American Airlines, retired – IASS 2000

Appendix 5

About the Author

Michel TREMAUD retired in September 2008 after serving the French commercial aviation industry for more than three decades, including serving Airbus for nearly 28 years.

He started piloting at age 17, flying fixed-wing aircraft as well as gliders and tow-planes.

He is a graduate engineer in aerospace engineering and also holds theoretical certificates as a professional pilot and as an airline pilot.

After graduation, he joined the French Air Ministry, for his military duty period, conducting performance evaluations of foreign military airplanes and exploring the feasibility and performance of a tanker aircraft based on the then-single Airbus model, the A300B4.

Then Michel joined the aviation branch of the French Bureau Veritas, as deputy-director at Le Bourget airport, conducting airworthiness oversight on behalf of the French DGAC and contributing to the implementation of the newly mandated concept of Quality Assurance among locally-based operators and MRO's.

Looking for hands-on field experience, he joined Air Martinique (a French private airline operating in the Caribbean area) as director of engineering.

Returning to France mainland, Michel joined Aerotour (a charter airline based in Paris Orly) in a similar role, before joining Airbus for the core part of his aviation career.

At Airbus, Michel held successive engineering and management positions in maintenance engineering, powerplant engineering, flight operations performance and procedures development, development and certification flight tests, flight operations safety enhancement, … before focusing on the development and deployment of customer-oriented safety strategies, initiatives and programs dedicated to the prevention of incidents and accidents.

In his various successive roles, Michel flew jump-seat with a variety of operators - as a flight operations and performance engineer – thus gaining a worldwide experience, both in terms of operating environments and in terms of cultures.

He also had the opportunity to contribute to the followings industry efforts :

- Pratt & Whitney - JT9D-7R4 and PW4000 Reliability Enhancement Working Groups;
- AIA - Volcanic Ash Task Force and Inclement Weather Committee;
- Flight Safety Foundation – CFIT / ALAR Action Group (CAAG), Runway Safety Initiative and Precision-like Approaches Project;
- Eurocontrol – Level Bust and Air / Ground Communications Toolkits, SKYbrary website initiative; and,
- Industry Safety Strategy Group (ISSG), established for the development and deployment of the Global Aviation Safety Roadmap, on behalf of ICAO.

After retirement, Michel continued to support the FSF Runway Safety Initiative and the Eurocontrol SKYbrary website.